Benchmarking River Water Quality in Malaysia

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THE water quality status of rivers in Malaysia has always been a cause for concern for various local authorities, government agencies as well as the public at large. Rivers in Malaysia are generally considered to be polluted with coherent examples such as Sg. Klang in Selangor (shown in Figure 1.1), Sg. Juru in Penang and Sg. Segget in Johor. From physical observation alone, one can deduce that something is not right with the current water quality condition of these rivers. From a scientific perspective though, it is still necessary to quantify the degree of pollution, in order to manage the pollution issues in a systematic and optimised fashion.

(a)

(b)

Figure 1.1 : (a) Domestic Discharge into Sg. Damansara (tributary of Sg. Klang), (b) Sg. Klang near Taman Sri Manja

What discerns a polluted state? How bad is the current condition? What are the necessary pollution sources that need to be further scrutinised and controlled? All these questions require an extensive degree of quantification, as rehabilitation measures and engineering control have a large cost implication; inappropriate planning and decision making may very well lead to the wastage of public funds.

BACKGROUND

In Malaysia, the existing methodology for river water quality classification and monitoring is quite extensive. In fact, the country's current water quality monitoring network is at par, if not better, than many developed countries. At the moment, Malaysia has over 1000 manual and automatic river water quality monitoring stations in 146 basins maintained by the Department of Environment (DOE) alone [1]. These exclude other stations maintained by other agencies such as the Department of Irrigation and Drainage (DID) as well as the respective state level agencies.

There are two primary methods employed to classify the river water quality monitored; the Water Quality Index (WQI), which in turn is rooted on the Interim National Water Quality Standards (INWQS), a set of standards derived based on beneficial uses of water.

HISTORY AND BASIS FOR CLASSIFICATION

In 1985, the government undertook a national study dubbed the *"Development of Water Quality Criteria and Standards for Malaysia"*, whose researchers consisted of a multidisciplinary team of experts from universities throughout the country. The study was carried out in four phases with the intention of developing a national "benchmark" of water quality conditions on a per parameter basis. The study had to be carried out, as just adopting foreign criteria to local conditions would not be suitable due to differences in environmental characteristics and climatology. A good case in point is the solubility of oxygen. In Malaysia, oxygen solubility is limited by our equatorial climate; cool climate countries in turn, tend to have higher oxygen solubility [3].

The study orientation was on the **beneficial uses** of water which was focused on, water for domestic water supply, fisheries and aquatic propagation, livestock drinking, recreation and agricultural use [2]. Over 120 physico-chemical and biological parameters were reviewed in the study and, in the end, the INWQS was drafted. The INWQS defined six classes (I, IIA, IIB, III, IV and V) referred to for classification **of rivers or river segments** based on the descending order of water quality vis-a-vis Class I being the "best" and Class V being the "worst".

INTERIM NATIONAL WATER QUALITY STANDARDS (INWQS)

Table 1.1 below is an excerpt of the INWQS whereas Table 1.2 defines its respective beneficial uses [1]. The water quality is considered to be suitable for a specific use (shown in Table 1.2) as long as it is within the range specified for the designated classes. Class I - III of the INWQS specifies the water quality level necessary to sustain macro-aquatic life, with varying degree of sensitivity. Fish is used as an indicator due to its economic value. The same is true for potable water supply, where conventional treatment systems should be able to treat Class II designated water source efficiently, whereas, more advanced treatment systems are required for a Class III designated water source. Class IV (and below) can still be used for irrigation, whereas Class V water sources are considered to have minimal beneficial usage.

Note that, however, there are far reaching implications to this approach in classification, both spatially and temporally. The water quality at a designated point in the same basin may differ from that at another location, depending on whether there are any alterations to ambient levels along that segment, particularly as a result of pollution. From general knowledge, one knows that moving down river typically results in worsened water quality conditions, as a result of anthropogenic activity. Therefore, the selection of a monitoring point within a basin must also take into consideration the potential water uses within that vicinity (or lack thereof), prior to benchmarking against the INWQS, only then can a representative assessment be done. Of course, it would better if all stretches along the basin is of pristine quality (between Class I and II), hence also broadening its beneficial use.

Temporal variations in water quality also may occur, due to seasonal flow variations as a result of precipitation. Water quality during the dry season may remain fairly constant with some variations (provided there are no serious external disturbances or draught). During the wet season, where precipitation is at its maximum, the water quality has the potential to get better or become worse, depending on input from runoff or non-point source pollution. If pollution from non-point sources, such as agricultural runoff, is significant, then one would expect to observe elevated levels of ammonium, nitrate and phosphate, originating from the organo-fertilisers used [4]. Thus it becomes quite clear; land-use activities have a significant effect on water quality, both spatially and temporally. This makes water quality classification and assessment even more difficult.

One can also then deduce that a particular basin cannot be designated a single specific class of representation due to the spatial and temporal influences discussed. Nonetheless, the INWQS serves as a good benchmarking tool for the beneficial uses stipulated therein, hence it can also form a basis for target water quality in river rehabilitation efforts.

WATER QUALITY INDEX (WQI)

In an attempt to simplify the extensive amount of data collected coherent to the parameters listed in the INWQS, an indexing system was introduced. A Water Quality Index (WQI) ascribes quality value to an aggregate set of measured parameters. It usually consists of sub-index values assigned to each pre-identified parameter by comparing its measurement with a parameter-specific rating curve, optionally weighted, and combined into the final index. The purpose of a WQI is to summarise large amounts of water quality data for a specific river into simple terms (*i.e.* one number and a statement such as "good"). This makes it easily understandable for communities in the river basin and for river basin management [5].

Table 1.1: Excerpt of the INWQS

Parameters	Unit	Classes					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	> 2.7
BOD_5	mg/l	1	3	3	6	12	> 12
COD	mg/l	10	25	25	50	100	> 100
DO	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH		6.5 - 8.5	6.5 - 9.0	6.5 - 9.0	5 - 9	5 - 9	-
Color	TUC	15	150	150	-	-	
Elec. Conductivity	µS/cm	1000	1000	-	-	6000	-
Floatables		NV	NV	NV	-	-	-
Salinity	%	0.5	1	-	-	2	-
Taste		NOT	NOT	NOT	-	-	-
Total Suspended Solids	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal + 2°C	-	Normal + 2°C	-	-
Turbidity	NTU	5	50	50	-	-	-
Fecal Coliform	counts/100ml	10	100	400	5000 (20000)[a]	5000 (20000)[a]	-
Total Coliform	counts/ 100 ml	100	5000	5000	50000	50000	>50000

Note :
NV = No visible floatable materials/debris   NOT = No objectionable taste

Table 1.2: INWQS Class Definitions

Class	Definition
I	• Conservation of natural environment. • Water supply I - Practically no treatment necessary (except by disinfection or boiling only). • Fishery I - Very sensitive aquatic species.
IIA	• Water supply II - Conventional treatment required. • Fishery II - Sensitive aquatic species.
IIB	• Recreational use with body contact.
III	• Water supply III - Extensive treatment required. • Fishery III - Common of economic value, and tolerant species; livestock drinking.
IV	Irrigation.
V	None of the above.

The WQI primarily used in Malaysia (also referred to as the DOE-WQI) is an opinion-poll formula where a panel of experts is consulted on the choice of parameters and on the weight age to each parameter [2]. Six parameters were chosen for the WQI; Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Suspended Solids (SS), Ammoniacal Nitrogen (AN) and pH. Calculations are performed not on the parameters themselves but on their sub-indices. The sub-indices are named SIDO, SIBOD, SICOD, SIAN, SISS and SIPH. The Best Fit Equations used for the estimation of the six sub-index values are shown below [1];

Subindex for DO (in % saturation): SIDO

$$
\begin{aligned}
SIDO &= 0 && \text{for } x \leq 8\ \% \\
&= 100 && \text{for } x \geq 92\ \% \\
&= -0.395 + 0.030\,x^2 - 0.00020\,x^3 && \text{for } 8\ \% < x < 92\ \%
\end{aligned}
$$

Subindex for BOD : SIBOD

$$
\begin{aligned}
SIBOD &= 100.4 - 4.23x && \text{for } x \leq 5 \\
&= 108e^{-0.055x} - 0.1 && \text{for } x > 5
\end{aligned}
$$

Subindex for COD : SICOD

$$
\begin{aligned}
SICOD &= -1.33x + 99.1 && \text{for } x \leq 20 \\
&= 103e^{-0.0157x} - 0.04x && \text{for } x > 20
\end{aligned}
$$

Subindex for AN : SIAN

$$
\begin{aligned}
SIAN &= 100.5 - 105x && \text{for } x \leq 0.3 \\
&= 94e^{-0.573x} - 5\,|x - 2| && \text{for } 0.3 < x < 4
\end{aligned}
$$

Subindex for SS : SISS

$$
\begin{aligned}
SISS &= 97.5e^{-0.00676x} = 0.05x && \text{for } x \leq 100 \\
&= 71e^{-0.0016x} - 0.015x && \text{for } 100 < x < 1000 \\
&= 0 && \text{for } x \geq 1000
\end{aligned}
$$

Subindex for pH : SIPH

$$
\begin{aligned}
SIPH &= 17.2 - 17.2x + 5.02x^2 && \text{for } x < 5.5 \\
&= -242 + 95.5x - 6.67x^2 && \text{for } 5.5 \leq x < 7 \\
&= -181 + 82.4x - 6.05x^2 && \text{for } 7 \leq x < 8.75 \\
&= 536 - 77.0x + 2.76x^2 && \text{for } x \geq 8.75
\end{aligned}
$$

Note :
x = concentration in mg/l for all parameters except pH

Once the respective sub indices have been calculated, the WQI can then be calculated as [1];

$$
\mathbf{DOE\text{-}WQI = 0.22*SIDO + 0.19*SIBOD + 0.16*SICOD + 0.15*SIAN + 0.16*SISS + 0.12*SIPH} \quad (1.1)
$$

The summation of the weight ages for all the sub-indices must have a value of unity. The respective class designation for the WQI scores in turn are tabulated below (Table 1.3 and Table 1.4);

LIMITATIONS OF THE WQI

Indexes by design contain less information than the raw data that they summarise; many uses of water quality data cannot be met with an index. Indexes are less suited to specific questions. Site-specific decisions should be based on **an analysis of the original water quality data**. In short, an index is a useful tool for communicating water quality information to the lay public and to legislative decision makers [6].

Besides being general in nature (imprecise), there are at least two reasons that an index may fail to accurately communicate water quality information. Firstly, most indexes are based on a pre-identified set of water quality constituents. A particular station may receive a good WQI score, and yet have water quality impaired by constituents not included in the index. This is inherent to the WQI used in Malaysia, where the six constituents used to ascribe water quality are mostly physico-chemical based, without consideration for coli form based indicators, relevant to skin contact (recreation) and even for potable water supply. Certain heavy metals, which may be carcinogenic, are also not included in the WQI.

Secondly, aggregation of data may mask short-term water quality problems. A satisfactory WQI at a particular station does not necessarily mean that

Table 1.3: DOE Water Quality Index Classification

Parameters	Unit	Classes				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	<0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
Biochemical Oxygen Demand (BOD_5)	mg/l	< 1	1 – 3	3 – 6	6 – 12	> 12
Chemical Oxygen Demand (COD)	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 – 5	1 – 3	< 1
pH	mg/l	> 7	6 – 7	5 – 6	< 5	> 5
Total Suspended Solids (TSS)	mg/l	< 25	25 – 50	50 – 150	150 – 300	> 300
Water Quality Index (WQI)	mg/l	> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

Table 1.4: DOE Water Quality Classification Based on Water Quality Index

Parameters	Index Range		
	Clean	Slightly Polluted	Polluted
SIBOD	91 – 100	80 – 90	0 – 79
SIAN	92 – 100	71 – 91	0 – 70
SISS	76 – 100	70 – 75	0 – 69
WQI	81 – 100	60 – 80	0 – 59

water quality was always satisfactory. This is related to the earlier discussion of temporal variations in water quality benchmarking using the INWQS. At best, the WQI is a reporting tool used to generally describe the water quality conditions at a specific location and time, in a manner which is easily understood by the general population.

In the event the WQI registers a value which is unacceptable to the relevant authorities and stakeholders, further scrutiny of the water quality conditions coherent to other parameters listed in the INWQS must be done. The problem that arises in the real world though is when the WQI registers a value which is good, though on-site conditions tell a different story. There is no straightforward answer for this conundrum, except to again, reflect back on the INWQS to benchmark the constituent level relative to specific beneficial use. The root cause of the contradiction must be identified through on-site field survey as there are numerous other reasons, besides the ones discussed previously, that can contribute to the variation.

CONCLUSION

In all, both the INWQS and WQI are good water quality benchmarking tools, albeit with certain limitations. More importantly is the effective utilisation of these tools by the responsible agencies and parties involved in watershed management. The authorities must be aware of the implications and limitations of benchmarking using the INWQS and WQI, so that river water quality preservation efforts can be executed seamlessly. ■

REFERENCES

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[4] A. R. A. Baginda and Z. Zainudin,"Keynote Paper : Moving Towards Integrated River Basin Management (IRBM) in Malaysia", The Institution of Engineers, Malaysia (IEM), Proceedings, 11th Annual IEM Water Resources Colloquium, ISBN 978-967-5048-46-3., 2009.

[5] K. Saffran, K. Cash, K. Hallard, B. Neary and R. Wright, "CCME Water Quality Index 1.0 User's Manual", Canadian Water Quality Guidelines for the Protection of Aquatic Life, Canadian Environmental Quality Guidelines, Canadian Council of Ministers of the Environment, 2001.

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NOTICE ON NOMINATION PAPERS FOR COUNCIL ELECTION SESSION 2010/2011

4th Announcement

Notice inviting nominations for the Election of Council Members for Session 2010/2011 will be posted on the IEM Notice Board and on the website on **5 January 2010** for the information of all Corporate Members. Following the close of nominations on **29 January 2010**, the election exercise will proceed. All Corporate Members residing overseas are requested to take note of the requirements of Bylaw section 5.11.

The voting paper shall, not less than twenty-eight (28) clear days before the date of the Annual General Meeting be sent by post to all Corporate Members residing in Malaysia and to any other Corporate Members who may in writing request to have the paper forwarded to him. The voting paper shall be returned to the Honorary Secretary in a sealed envelope so as to reach him by a specified date not less than seven (7) days before the Annual General Meeting.

Voting papers are expected to be mailed by 2 March 2010.

Corporate Members residing outside Malaysia, who wish to receive voting papers, are advised to write to the Honorary Secretary on or before 1 January 2010.

Thank you.